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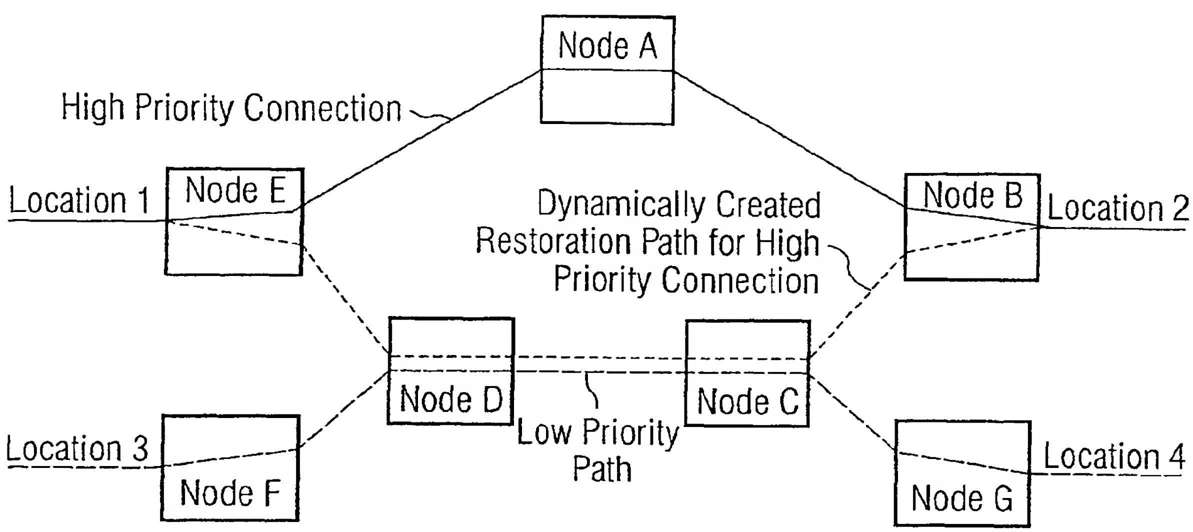
(54) A method of controlling data routing on a network

(57) A method of controlling data path routing in a network comprises assigning to a path a priority for connection, reconnection and holding; calculating a route for the path as a series of links between nodes (A to G); allocating resources to the path at each link that it traverses, taking the resources from lower priority paths if required; monitoring for failure of any link and disconnecting any path using the link resulting in path failure according to the holding priority of the path or monitoring for a connect request according to connect priority of the new path; on occurrence of a failure or connect request, searching for a suitable route with free capacity; if no suitable route has free capacity, then searching for a route which has sufficient capacity allocated to paths with a lower holding priority than the reconnect priority of the path where the link has failed, or the connect priority of the new path; taking over at each link the resources of the path with the lower priority, such that the path is re-connected or the new path is connected; and checking that a path with a lower priority whose resources are taken has the lowest holding priority of any such path on each link.



EP 1 289 208 A2

Description

[0001] This invention relates to a method of controlling data routing on a network.

[0002] In a network, for example a telephone network, paths are created with different priorities. In general, paths are allocated different priorities according to their status and the action required, e.g. a connect priority, reconnect priority and holding priority. Where a link in a high priority path fails, it is important to reconnect it as soon as possible. Networks are often set up with redundant links that can be taken over by high priority paths immediately. However, this results in the under utilisation of the network components and reduces the total amount of traffic which can be sent. A system has been proposed in which a low priority path is taken over to enable a failed link in a high priority path to be reconnected. However, this relies on the fault being spotted by a supervisor, a request to the nearest lower priority path being sent to release that path, then the high priority path being connected through the link requested. This is time consuming and rarely the most efficient use of resources.

[0003] Another system is described in US 6,151,304 in which a network is set up to the extent that there is no contention over routes, then a parallelisation mechanism is applied to further reduce contention by permitting multiple demands to be routed in parallel. However, this system relies on pre-computing a suitable route in the case of failure, then instructing it to be set up if a failure occurs. However, if the path is pre-computed then the pre-computed restoration path needs to be updated whenever there is a change in the network.

[0004] In accordance with the present invention a method of controlling data path routing in a network comprises assigning to a path a priority for connection, reconnection and holding; calculating a route for the path as a series of links between nodes; allocating resources to the path at each link that it traverses, taking the resources from lower priority paths if required; monitoring for failure of any link and disconnecting any path using the link resulting in path failure according to the holding priority of the path or monitoring for a connect request according to connect priority of the new path; on occurrence of a failure or connect request, searching for a suitable route with free capacity; if no suitable route has free capacity, then searching for a route which has sufficient capacity allocated to paths with a lower holding priority than the reconnect priority of the path where the link has failed, or the connect priority of the new path; taking over at each link the resources of the path with the lower priority, such that the path is re-connected or the new path is connected; and checking that a path with a lower priority whose resources are taken has the lowest holding priority of any such path on each link.

[0005] The present invention is able to maintain a high utilisation of the system, whilst being able to take over link resources from a lower priority path as soon as a fault develops on a high priority path. Where a failure has occurred, the paths may revert to their original routes after the failure has been rectified, thereby minimising the down time for the lower priority path as well as providing an effective method of keeping high priority paths connected. The present invention minimises the number of redundant components required and allows much higher utilisation of the network, without the overhead involved in pre-computing the possible alternatives in case of failure.

[0006] Low priority paths are able to use capacity in the network whilst there is no failure condition on the provisioned paths, but these low priority paths are taken over if their capacity is required to restore a high priority path. By doing the calculation of the restoration path at failure time the best restoration path at the time of failure can be calculated.

[0007] The invention is applicable to various networks, such as multi-protocol label switching networks, asynchronous transfer mode networks, synchronous digital hierarchy networks and voice networks, but preferably, the network comprises an automatically switched optical network.

[0008] Preferably, each priority is allocated a value between 1 and 4.

[0009] An example of a method of controlling data routing on a network according to the present invention will now be described with reference to the accompanying drawing in which:-

Figure 1 illustrates a network in which the paths are routed by a method according to the invention.

[0010] In a network having nodes and links between the nodes, a path is set up between a start and end point. The path is allocated a set of priorities for connection, i.e. set up priority during service provisioning; re-connection, i.e. set up priority during failure recovery; and holding, i.e. priority once established. The priorities for each state are preferably set to an integer value between 1 and 4, where 1 is the highest priority, although other systems are equally appropriate. Before taking over link resources between two nodes to restore a path after failure, the system applies the method of the present invention to assess first whether there is a link with free capacity, then whether there is a link with paths with a lower holding priority than the re-connect priority of the path requiring restoration; and if this is true, that these paths have the lowest holding priority of any possible such paths to reconnect the path. Only having satisfied this third requirement, does the system take over the link resources in question to disconnect the lower priority path and allow the higher priority path to reconnect or to connect through that link.

[0011] The present invention allows for link resources allocated to lower priority paths to be taken over to enable restoration of higher priority paths if a failure occurs, or by higher priority paths being connected when subscriber

requirements change. The system also supports arbitration between different path connections if there is competition over resources when the paths are first set-up. When arbitrating between paths, only one of each path's priority attributes is used. Which one depends on the path's state. Thus during initial set-up, the connect priority is used. Once the path has been established, the holding priority is used and in the event that restoration is required, the re-connect priority is used.

[0012] By way of example, a network that supports connections of a single fixed bandwidth is described. In such a network, link capacity and utilisation can be specified as a number of paths. However, the invention can also be applied to networks that support paths with variable bandwidths. Each node holds the following database for each of its links.

Link Capacity	total number of connections that the link can support
Priority 1 utilisation	number of established connections at holding priority 1
Priority 2 utilisation	number of established connections at holding priority 2
Priority 3 utilisation	number of established connections at holding priority 3
Priority 4 utilisation	number of established connections at holding priority 4

[0013] This information is flooded throughout the network using a link state protocol. Note that priority level utilisation information is only distributed for those priorities that have established connections. This optimises the signalling traffic volume.

[0014] In the following the term pre-empt is defined to mean the act of taking the link resources currently allocated to a path (the pre-empted path) and disconnecting that path, with the intention of re-allocating those resources to another path (the pre-empting path).

[0015] When a connection is initially set up or restored, the method applies the following procedures in support of a connection priority. A routing algorithm implements the following rules:

1. A path is only pre-empted if no path with free capacity, and which satisfies any constraints or requirements specified, is found;
2. If a path is pre-empted, then the path pre-empted must have a lower holding priority than the connect or re-connect priority of the new path;
3. If a path is pre-empted, then it must have the lowest possible holding priority of all established paths on that link.

[0016] The routing algorithm finds the optimal route obeying these rules by performing iteratively a basic routing algorithm until it is successful, at each iteration increasing the scope of existing connections that can be pre-empted, as described by the pseudo code in Table 1 below. By way of example, in the algorithm below, the basic algorithm is the constraint shortest path first algorithm. However, other basic algorithms can be used such as widest shortest path first.

```
if initial setup
        this_priority = connect priority
else
        this_priority = re-connect priority
endif

for each link
        capacity = link_capacity
        for each priority i
                capacity = capacity - priority_i_utilization
        end for
end for

next_preempt_priority = 4

repeat
        perform basic CSPF
        if path found
                exit success
        else if next_preempt_priority <= this_priority
                exit failure
        else
                for each link
                i = next_preempt_priority
                        capacity = capacity + priority_i_utilization
                end for
                next_preempt_priority = next_preempt_priority – 1
        end if
end repeat
```

[0017] A specific example of a network in which the method of the present invention is applied is illustrated in Fig. 1. This shows a network having 7 nodes, A to G and four locations 1 to 4. A connection path is set up between locations 1 and 2, running through nodes E, A and B using a known routing algorithm, such as constrained shortest path first (CSPF). A second path is set up between locations 3 and 4, running through nodes F, D, C and G. The priorities allocated to this second path are lower than those allocated to the first path. In this example, the links only have the resources to create one path, so if there is a failure of the link along the path between 1 and 2, then a restoration path is dynamically created between 1 and 2 via nodes D and C, and the path between 3 and 4 is severed. Before taking over the resources of the link between D and C, the system applies the method of the present invention to assess first whether there is a route across links with free capacity, then whether there is a route across links carrying paths with a lower holding priority than the re-connect priority of the path from 1 to 2; and when doing this, it is ensured that these links carry paths with the lowest holding priority of any possible such links to reconnect the path from 1 to 2 by first considering resources allocated to paths with the lowest holding priority, then the next lowest holding priority and so on. At each link where existing paths have to be pre-empted to free resources, the ones with the lowest holding priority of any possible paths are pre-empted.

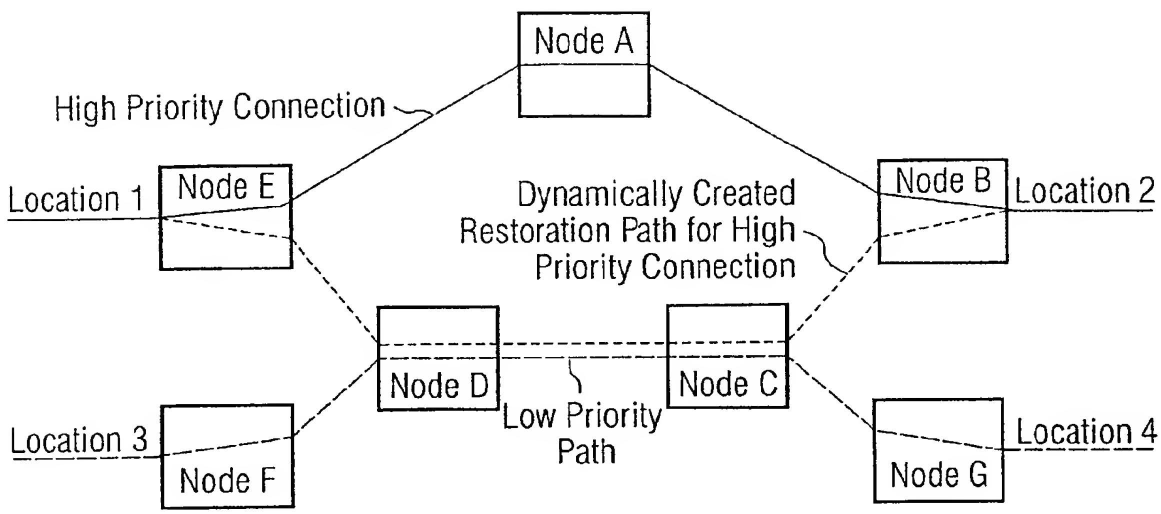
[0018] The present invention is applicable to any type of network that supports paths or connections, but is particularly suitable for increasing efficiency of utilisation of automatically switched optical networks.

Claims

1. A method of controlling data path routing in a network, the method comprising assigning to a path a priority for connection, reconnection and holding; calculating a route for the path as a series of links between nodes; allocating resources to the path at each link that it traverses, taking the resources from lower priority paths if required; monitoring for failure of any link and disconnecting any path using the link resulting in path failure according to the holding priority of the path or monitoring for a connect request according to connect priority of the new path; on occurrence of a failure or connect request, searching for a suitable route with free capacity; if no suitable route has free capacity, then searching for a route which has sufficient capacity allocated to paths with a lower holding priority than the reconnect priority of the path where the link has failed, or the connect priority of the new path; taking over at each link the resources of the path with the lower priority, such that the path is re-connected or the new path is connected; and checking that a path with a lower priority whose resources are taken has the lowest holding priority of any such path on each link.

2. A method according to claim 1, wherein the network comprises an automatically switched optical network.

3. A method according to claim 1 or claim 2, wherein each priority is allocated a value between 1 and 4.


Node A
High Priority Connection
Location 1
Node E
Node B
Location 2
Dynamically Created
Restoration Path for High
Priority Connection
Node D
Node C
Low Priority
Path
Location 3
Node F
Node G
Location 4

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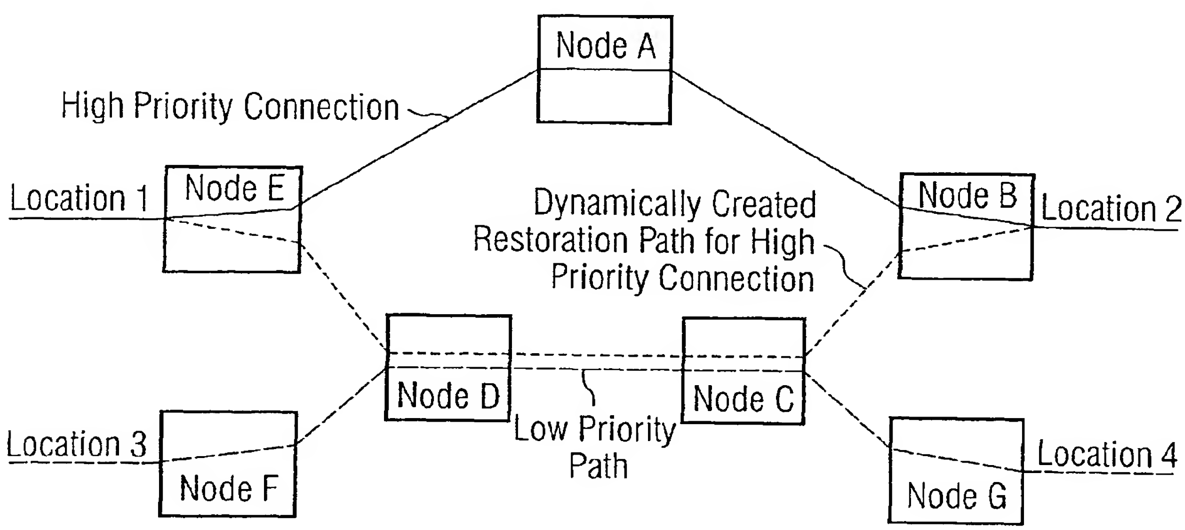

EP 1 289 208 A3

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EUROPEAN SEARCH REPORT

Application Number
EP 02 07 8112

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	PEYRAVIAN M ET AL: "Connection preemption: issues, algorithms, and a simulation study" 7 April 1997 (1997-04-07), INFOCOM '97. SIXTEENTH ANNUAL JOINT CONFERENCE OF THE IEEE COMPUTER AND COMMUNICATIONS SOCIETIES. DRIVING THE INFORMATION REVOLUTION., PROCEEDINGS IEEE KOBE, JAPAN 7-11 APRIL 1997, LOS ALAMITOS, CA, USA,IEEE COMPUT. SOC, US, PAGE(S) 143-151 , XP010252021 ISBN: 0-8186-7780-5 * page 143, left-hand column, line 17 - right-hand column, line 25 * * page 144, left-hand column, line 4 - line 7 * * page 144, left-hand column, line 39 - line 44 * * page 145, left-hand column, line 31 - right-hand column, line 17 * -----	1-3	H04L12/56 H04L12/56
A	EP 0 714 192 A (INTERNATIONAL BUSINESS MACHINES CORPORATION) 29 May 1996 (1996-05-29) * page 4, line 26 - line 31 * -----	1	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H04L
A	US 6 262 974 B1 (CHEVALIER DENIS ET AL) 17 July 2001 (2001-07-17) * column 3, line 6 - line 36 * * column 9, line 32 - line 51 * -----	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	4 August 2005	Brichau, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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2

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 02 07 8112

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82